

# Spotlight on Teachers

James Lewis

This article discusses three recent reports that share two themes: good teachers matter and the education of mathematics teachers has special importance. *Before It's Too Late* can be viewed as a political answer to an issue of national importance. *Educating Teachers of Science, Mathematics, and Technology* provides a review of research that makes the case for the importance of a well-prepared teacher and then advocates a fundamental restructuring of teacher preparation and professional development. Finally, *The Mathematical Education of Teachers* offers a discipline-based response to the question of how best to educate future teachers of mathematics.

Clearly, the American public believes our K-12 schools need to be improved. K-12 education was a major issue in the recent presidential election. There is no shortage of political solutions, including vouchers, charter schools, reductions in class size, and high-stakes testing for students and for teachers. But despite all the other suggestions for how to improve our schools, one idea recurs frequently—good teachers matter. This idea is often combined with the viewpoint that our colleges and universities are not doing enough to produce high-quality teachers.

Increasingly, special attention is paid to the need for K-12 students to improve their achievement in mathematics and science and to the need to improve the education of mathematics and science teachers. But we are also told that teacher education can no longer be the responsibility only of universities' schools of education. Instead, it must become a high priority for faculty who teach in arts and sciences departments.

The three reports cited above can be read as a blueprint for mathematicians to play a role both in solidifying consensus about the need for better

mathematics achievement by U.S. students and in bringing about that achievement by helping to prepare well-educated mathematics teachers able to teach to high standards.

*Before It's Too Late* plows important ground. It is the work of a national commission appointed by the U.S. Secretary of Education. Comprised primarily of policymakers, not mathematicians or scientists, the commission argues that education in mathematics and science has special importance for our nation. It argues that the nation should be willing to invest significant resources to achieve improved performance in mathematics and science in our K-12 schools. And it argues strongly that improved mathematics and science teaching is the most effective way to achieve these gains. *Educating Teachers of Science, Mathematics, and Technology* provides the research base for the importance of well-prepared teachers. It calls for significant changes in the education and professional development of teachers. However, it does not delve into what mathematics a teacher needs to know or how a teacher comes to know that mathematics. This work is left for *The Mathematical Education of Teachers*. Thus each of these three reports serves a different purpose and complements the work of the others.

## Before It's Too Late

Richard Riley, then U.S. Secretary of Education, chose July 20, 1999, the thirtieth anniversary of the first landing on the Moon, to announce the appointment of the 25-member National Commission on Mathematics and Science Teaching for the 21st Century. The membership included two governors; two U.S. senators; two members of the U.S. House of Representatives; the presidents of The Ohio State University and Morehouse College; a former chancellor of the University of California, Berkeley; the chief executive officers of Intel and State Farm; the president of the American Federation of Teachers; and former U.S. Senator John Glenn, who was appointed

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as commission chairman. Because of the prominence of its chairman, the Commission is known as the "Glenn Commission".

The charge from Secretary Riley asked the commission to investigate and report on the quality of K-12 mathematics and science teaching in the nation and to consider ways of improving the recruitment, preparation, retention, and professional growth of teachers. He called on the commission "to set the stage for advancement in mathematics and science for the next thirty years."

On September 27, 2000, the commission officially released its report. It asserts that "the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically." *Before It's Too Late* is centered on two core premises:

1) America's students must improve their performance in mathematics and science if they are to succeed in today's world and if the United States

### Before It's Too Late

Report of the National Commission on Mathematics and Science Teaching for the 21st Century. Available on the Web at <http://www.ed.gov/ameriacounts/glenn/>. For paper copies contact: ED PUBS, Education Publications Center, U.S. Department of Education, P.O. Box 1398, Jessup, MD 20794-1398; telephone toll-free 1-877-433-7827; fax 301-470-1244; e-mail: [edpubs@inet.ed.gov](mailto:edpubs@inet.ed.gov).

#### Commission Members

John Glenn (Commission Chair) Astronaut and former U.S. Senator, Ohio	Javier Gonzalez Mathematics Teacher Pioneer High School, California	William E. Kirwan President, The Ohio State University
Linda P. Rosen (Commission Executive Director) Senior Advisor in Mathematics and Science Education U.S. Department of Education	Jerilyn Grignon Technology Instructor Menominee Indian Junior High School, Wisconsin	Maria Alicia Lopez-Freeman Executive Director California Science Project
Deborah Loewenberg Ball Arthur F. Thurnau Professor of Mathematics Education and Teacher Education University of Michigan	Jeffrey Himmelstein Adjunct Professor of Biology William Paterson University	Walter E. Massey President, Morehouse College
Craig R. Barrett President and Chief Executive Officer Intel Corporation	Rush Holt U.S. Representative, New Jersey	Iris T. Metts Superintendent of Schools Prince George's County Public School System, Maryland
Diane Briars Mathematics Director Pittsburgh Public Schools	James B. Hunt Jr. Governor of North Carolina	Connie Morella U.S. Representative, Maryland
Cynthia Moore Chestnut Member, Florida House of Representatives	James M. Jeffords U.S. Senator, Vermont	Dennis Van Roekel Secretary-Treasurer National Educational Association
Sandra Feldman President, American Federation of Teachers	Anne Jolly Science Department Chair Cranford Burns Middle School, Alabama	Edward B. Rust Jr. Chairman and Chief Executive Officer State Farm Mutual Automobile Insurance Company
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is to stay competitive in an integrated global economy.

2) The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching.

The report begins by recalling Goal 4 of the *National Education Goals*, first issued by the nation's governors in September 1989:

By the Year 2000, United States students will be first in the world in mathematics and science achievement.

Then, after stating the obvious ("our effort since has not matched our rhetoric"), the commission cites TIMSS (Third International Mathematics and Science Study) and NAEP (National Assessment of Educational Progress) data and concludes:

In an age now driven by the relentless necessity of scientific and technological advance, the preparation our students receive in mathematics and science is, in a word, unacceptable.

To further make the case for a national focus on mathematics and science education, the commission offers four "important and enduring" reasons why our children need to achieve competency in mathematics and science: (1) the demands of our changing economy and workplace, (2) our democracy's continuing need for a highly educated citizenry, (3) the vital links of mathematics and science to the nation's national security interests, and (4) the deep value of mathematical and scientific knowledge.

Despite the failure of the nation to adequately respond to the challenges presented by the *National Education Goals*, the commission believes "an unusual confluence of factors has created an unprecedented—perhaps once-in-a-lifetime—opportunity for making progress." It offers five major factors that make this a good time to focus on strengthening mathematics and science education: (1) reform efforts have sharply focused the attention of the American people on education as a public issue; (2) the nation now has a surplus of resources to invest in education; (3) a coming demographic shift in the teaching force—two-thirds will retire in the next decade—offers an unparalleled chance to plan for and make changes at the core of education itself; (4) much has been learned in the past generation about curriculum, high standards, effective teaching, assessment, and how children learn; and (5) the new generation of college graduates is once again showing an interest in teaching as a profession.

The commission sets forth three goals to guide a national effort.

**Goal 1:** Establish an ongoing system to improve the quality of mathematics and science teaching in grades K-12.

**Goal 2:** Increase significantly the number of mathematics and science teachers and improve the quality of their preparation.

**Goal 3:** Improve the working environment for K-12 mathematics and science teachers and make the teaching profession more attractive.

Action strategies are put forward as the commission's recommendations for achieving the three goals. They include making salaries of teachers more competitive and offering special incentives (e.g., cash awards, salary increases) for the highest-achieving mathematics and science teachers. Several of the strategies involve a direct role for higher education:

*Summer Institutes:* The commission proposes the creation of two-week summer institutes to address the most pressing problems, such as providing opportunities for upgrading content knowledge of out-of-field teachers, conducting subject-based workshops for all science and mathematics teachers, integrating technology into the teaching of mathematics and science, and improving skills for teaching specific subject matter by grade. States should make regular institute attendance a critical component of teacher recertification, the report says.

*Exemplary Models:* Identifying exemplary teacher preparation programs and finding ways to encourage others to multiply their success is a key to achieving Goal 2. Becoming an exemplary program would be the result of a highly selective process, with a program needing to be reviewed every five years if it is to retain designation as an exemplary program.

*Mathematics and Science Teaching Academies:* An entirely new kind of research- and school-based preparation is envisioned to provide a one-year teacher education program for those with scientific and mathematical content knowledge. Fifteen such academies would be competitively selected.

*Teacher Recruitment:* Three major scholarship and loan programs are envisioned to help attract talented people to become mathematics and science teachers. Annually, 3,000 recent college graduates and persons at midcareer with baccalaureate degrees in mathematics or science would be chosen as "fellows" to attend the Mathematics and Science Teaching Academies. They would receive a \$30,000 stipend for the year in return for a five-year commitment to teach in districts with math and science teacher shortages. In addition, 1,500 high school students would receive full-tuition scholarships to attend one of the exemplary teacher preparation institutions in return for a five-year commitment to teach in an area with teacher shortages. Finally, up to 6,000 students would receive federally funded loans, with the loans being forgiven contingent upon the students' agreeing to teach in districts with shortages of mathematics and science teachers.

The Glenn Commission report focuses on the importance of high-quality teaching in mathematics and science and states that teachers must have a “deep knowledge of subject matter.” The report also discusses the importance of the process of inquiry, the need for ongoing professional development, and the need for time “within the school day” to keep up with new developments in the teacher’s field.

Is the nation ready to pay for high-quality teaching in mathematics and science? In a foreword to the report, commission chairman John Glenn writes: “The task to which we call the American people is therefore not an easy one. Nor will our goals be met at bargain-basement rates.” The commission puts a price tag on its recommendations, calling for business, foundations, and federal, state, and local governments to spend a total of over \$5 billion per year to achieve the goals set forth in the report.

Those of us in the mathematics community should not miss the significance of the Glenn Commission and its report. The U.S. Secretary of Education appointed this blue-ribbon panel and charged it to focus on mathematics and science teaching. The panel, most of whom do not have a professional connection to mathematics or science, issued a report that says our ability to educate our children in mathematics and science has special importance to the nation. Following release of the report, U.S. Representatives Rush Holt and Connie Morella introduced a bill in Congress to implement many of the recommendations of the report. Senator Glenn has been giving numerous speeches, urging public support for the commission’s recommendations.

We in mathematics should recognize that this public attention to and support for the importance of mathematics is special, but it may also be short lived. While the spotlight is on educating teachers, especially mathematics teachers, we need to respond with a willingness to meet national needs in this important area and with a creativity that can lead to better K-12 teachers of mathematics.

### **Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium**

In [NRC, 1999] the National Academies called for a decade of research devoted to improving education. A primary focus is to resolve issues about the most effective ways to improve teaching. It was in this context that the National Research Council (NRC) established the Committee on Science and Mathematics Teacher Preparation (CSMTP) and charged it with identifying critical issues in existing practices and policies for K-12 teacher preparation in science and mathematics. Funding was provided by the National Science Foundation.

In its assessment of the current status of education for teachers of science, mathematics, and technology, the CSMTP argues that good teaching does matter and finds the current system for educating teachers lacking. Among the committee’s findings are the following:

- Many of the nation’s teachers are not adequately prepared to teach science, mathematics, and technology.
- The preparation many colleges and universities provide to those intending to become teachers does not meet the needs of the modern classroom.
- Many professional development programs for continuing teachers do little to enhance teachers’ content knowledge or the techniques and skills they need to teach science and mathematics effectively.
- Approximately one-third of all secondary school teachers of mathematics have neither a major nor a minor in mathematics, mathematics education, or in such related disciplines as engineering or physics.

In discharging its duty to examine the relevant research and to identify recommendations from professional organizations, the committee paid special attention to the critical importance of well-prepared teachers for student learning and achievement. Indeed, many of the more than two hundred references cited in this report are used to support this thesis. For example, Sanders and Rivers [SR] reported on test or achievement data for a cohort of students in Tennessee from the time they were second-graders to the time they had completed fifth grade. By disaggregating the data, the researchers were able to see the impact of quality teaching on each child over time. They reported that student achievement at each grade level correlated positively with the quality of the teachers who taught those students. Later, Wright, Horn, and Sanders [WHS] found that “teacher effects are dominant factors affecting student academic gain,” especially in mathematics.

Special attention is paid to the question of what level and type of mathematics (or science) knowledge K-12 teachers need. The research cited includes work of Ball [B1] and Cooney [C], who argue that content knowledge must be a central focus and an integral part of a mathematics teacher’s preparation program. Later, Ball [B3] contends that, to teach mathematics effectively, a teacher must have knowledge of mathematics and a conceptual understanding of the principles underlying its topics, rules, and definitions. Later, Manouchehri [Man] states flatly that the research literature supports the notion that “in the absence of conceptual understanding of content, effective teaching is highly improbable.”

Ma’s work [Ma] is cited for offering evidence that a “deeper understanding both of mathematics content and its application allowed Chinese teachers

to promote mathematical learning and inquiry more effectively than their counterparts in the United States.” Ma indicates various distinctions between the teaching environment for Chinese and U.S. teachers that might offer insight for improving U.S. education. For example, Chinese mathematics teachers teach only mathematics, and they teach at most three to four classes a day, so that the rest of their day is available for shared study and conversation with fellow teachers.

In discussing what mathematics a K-12 teacher should know, the report uses the concept of “pedagogical content knowledge” first introduced by Shulman [S]. Grouws and Schultz [GS] describe the concept when they state, “In mathematics, pedagogical content knowledge includes, but is not limited to, useful representations, unifying ideas, clarifying examples and counterexamples, helpful analogies, important relationships, and connections among ideas. Thus, pedagogical content knowledge is a subset of content knowledge that has particular utility for planning and conducting lessons that facilitate student learning.”

Having made the case that ensuring a well-prepared teacher in each mathematics (and science) classroom is the single most important action the nation can take to improve student learning,

*Educating Teachers* argues that significant improvement will not result from each distinct participant in the process (teacher educators, school districts, mathematics and science faculty, two-year and four-year colleges, etc.) working independently. In searching for a better way to educate teachers, the committee paid particular attention to what is known as a Professional Development School (PDS), which is a partnership between a college or university and the K-12 sector. A PDS provides teacher education and also aims to improve teaching and learning in the schools. In the view of the committee, the PDS model has much in common with how physicians are educated: Partnerships between medical schools and their teaching hospitals facilitate collaboration between teaching and clinical faculty in the education of new generations of physicians.

With these examples to guide them, the CSMTTP proposes “a new level of partnership between K-12 schools and the higher education community that is designed to ensure high-quality teacher education.” The goal of such partnerships would be to share responsibility for both the education of future teachers and the professional development of current teachers. The CSMTTP proposed six

**Educating Teachers of Science, Mathematics, and Technology:  
New Practices for the New Millennium**

A report of the Committee on Science and Mathematics Teacher Preparation, National Research Council. The report is available through National Academies Press, 2101 Constitution Avenue, NW, Box 285, Washington, DC 20055; telephone 800-624-6242 or 202-334-3313; World Wide Web <http://www.nap.edu/>.

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“Guiding Principles” for improving teacher education in science, mathematics, and technology:

1) The improvement of teacher education and teaching in science, mathematics, and technology should be viewed as a top national priority.

2) Teacher education must become a career-long process. High-quality professional development programs that include intellectual growth as well as the upgrading of teachers’ knowledge and skills must be expected and essential features in the careers of all teachers.

3) Through changes in the rewards for, incentives for, and expectations of teachers, teaching as a profession must be upgraded in status to the level of other professions.

4) Both individually and collectively, two- and four-year colleges and universities must assume greater responsibility and be held more accountable for improving teacher education.

5) Neither the higher education nor K–12 communities can successfully improve teacher education as effectively in isolation as they can by working closely together. Collective, fully integrated efforts are needed among school staff and administrators in individual schools and districts, teachers’ unions, faculty and administrators in institutions of higher education, policymakers from local colleges and universities, and parents.

6) Many more scientists, mathematicians, and engineers must become well informed enough to be involved with local and national efforts to provide the appropriate content knowledge and pedagogy of their disciplines to current and future teachers.

The report gives examples of partnerships that include many of the components envisioned by the CSMTP and discusses ways in which the committee’s vision goes beyond the examples available today. Responsibility for student-teaching experiences would be vested primarily in school districts. In turn, professional development would be the responsibility of the higher-education partners. Master teachers in partner school districts would become “clinical faculty” for the college or university partner. In turn, collegiate faculty—in schools of education and in mathematics and science departments—would assume greater responsibility for the continuing professional education of teachers in the partner school district(s). University partners whose primary mission includes research would make it a priority to support research that focuses on ways to improve teacher education. Numerous recommendations are offered to governments, the higher-education and K–12 education communities, and professional societies, all designed to support the following general recommendations.

1) Teacher education in science, mathematics, and technology should be viewed as a continuum of programs and professional experiences that

enables individuals to move seamlessly from college preparation for teaching to careers in teaching these subject areas.

2) Teacher education should be viewed as a career-long process that allows teachers of science, mathematics, and technology to acquire and regularly update the content knowledge and pedagogical tools needed to teach in ways that enhance student learning and achievement in these subjects.

3) Teacher education should be structured in ways that allow teachers to grow individually in their profession and to contribute to the further enhancement of both teaching and their disciplines.

### **The Mathematical Education of Teachers**

The Mathematical Education of Teachers (MET) Project was initiated in 1997 by COMET, the Committee on the Mathematical Education of Teachers of the Mathematical Association of America (MAA). The project coincided with the updating of the standards of the National Council of Teachers of Mathematics [NCTM2]. Funding was sought and received from the U.S. Department of Education to support the work on the project. At the time of this writing, the report was scheduled for release in the spring of 2001. The committee, whose members are listed in an accompanying sidebar, received substantial assistance from Department of Education program officer Carole Lacampagne.

*The Mathematical Education of Teachers* was to build upon earlier work, especially *A Call for Change* [MAA] and the *Professional Standards for Teachers of Mathematics* [NCTM1]. However, the leadership of the MAA recognized that a broad base of support for these documents was never developed within the mathematics community, and thus they did not influence the mathematics education of teachers to the degree desired. Thus, the MET Project was envisioned as a joint effort of the major mathematics professional organizations. At a meeting in December 1997 the Conference Board of the Mathematical Sciences (CBMS) agreed to accept responsibility for the broad oversight of the MET Project. CBMS’s goal was to jointly prepare recommendations and strategies for bringing about significant improvement in the mathematics education of future teachers.

One early decision of the steering committee was that the target audience for the MET report would be the faculty who teach mathematics and statistics in our colleges and universities. By contrast, the Glenn Commission report is primarily targeted at national, state, and local policymakers, and the NRC report is designed to speak both to government policymakers and to college and university leaders. In a sense, the latter two documents focus attention on the importance of improving mathematics (and science) achievement in our K–12 schools and the key role of improving the education of teachers, but

they leave to the profession (and to documents like *The Mathematical Education of Teachers*) the responsibility for deciding how best to educate teachers of mathematics.

*The Mathematical Education of Teachers* addresses four distinct audiences: (1) department leaders, especially department chairs; (2) rank and file faculty in departments; (3) faculty who are occasionally assigned to teach a mathematics course for future teachers and who may need advice regarding how to design a useful course; and (4) faculty who accept leadership roles in designing and offering courses for future mathematics teachers. Speaking effectively to the first two groups requires a concise document that argues that the education of teachers of mathematics should be an important part of the mission of most mathematics departments. Those in the third group may need a quick tutorial as to what they should expect from an audience of future elementary school teachers. Finally, the fourth group needs a substantial resource.

The organization of *The Mathematical Education of Teachers* is designed to meet the needs of each of these audiences. The steering committee's recommendations appear early in Chapter 2 of the report. Chapters 3, 4, and 5 offer a brief introduction to the mathematics needed by teachers at the elementary, middle, and high school level; and more

detailed discussion is found in Chapters 7, 8, and 9. There will be two versions of the report: an "executive summary" version, which includes only Chapters 1-6, and the complete version, which includes all nine chapters.

Two general themes guide the report:

1) the intellectual substance in school mathematics; and

2) the special nature of the mathematical knowledge needed for teaching.

Much mathematics education research over the past decade or so has contributed to the understanding that substantial mathematical understanding is needed to teach well even topics like whole number arithmetic. In particular, the work of Ball (see, for example, [B1], [B2], and [B3]) and Ma [Ma] have helped persuade research mathematicians of this view. In addition to urging mathematicians to recognize their role in the education of future teachers of mathematics, the report stresses the idea that the mathematical knowledge needed for teaching mathematics is quite different from that required, for example, by a future engineer, physicist, or economist.

The recommendations of *The Mathematical Education of Teachers* are:

1) Prospective teachers need mathematics courses that develop a deep understanding of the mathematics they will teach.

### The Mathematical Education of Teachers

This report will be issued by the Conference Board of the Mathematical Sciences in the spring of 2001. At the time of this writing, a draft of the report was available on the Web at <http://www.maa.org/metdraft/index.htm>.

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2) While the quality of mathematical preparation is more important than the quantity, the following recommendations for the amount of mathematics coursework for teachers are offered:

i) Elementary grade teachers (K-4) should take at least 9 semester-hours of mathematics courses on fundamental ideas of elementary school mathematics.

ii) Middle-grade teachers of mathematics should take at least 21 hours of mathematics, including 12 on fundamental ideas of school mathematics for middle-level teachers.

iii) High school teachers should complete the equivalent of an undergraduate major in mathematics, including a 6-hour capstone course connecting college mathematics courses with high school mathematics.

3) Courses about school mathematics should focus on a thorough development of basic mathematical ideas. All courses designed for prospective teachers should develop careful reasoning and mathematical "common sense" in analyzing conceptual relationships and in applied problem-solving.

4) Along with building mathematics knowledge, mathematics courses for prospective teachers need to develop the habits of mind of a mathematical thinker and to demonstrate flexible, interactive styles of teaching.

5) Teacher education must be recognized as an important part of mathematics departments' mission at institutions that educate teachers. More mathematics faculty should consider becoming deeply involved in K-12 mathematics education.

6) The mathematical education of teachers should be seen as a partnership between mathematicians and mathematics educators.

7) There needs to be greater cooperation between two- and four-year colleges in the mathematical education of teachers.

8) There need to be more collaborations between mathematics faculty and school mathematics teachers.

9) Efforts to improve standards for school mathematics instruction, as well as for teacher preparation, accreditation, and certification, will be strengthened by the full-fledged participation of the academic mathematics community.

10) Teachers need the opportunity to develop their understanding of mathematics and its teaching throughout their careers, through self-directed and collegial study and through formal coursework.

11) Mathematics in middle grades should be taught by mathematics specialists, starting at least in the 5th grade.

Ideally, *Before It's Too Late* and *Educating Teachers of Science, Mathematics, and Technology* will succeed in focusing the nation's attention (and resources) on the importance of well-prepared

teachers of mathematics in improving K-12 mathematics education in the U.S. In turn, *The Mathematical Education of Teachers* will ideally facilitate mathematicians' efforts to improve the mathematical education of teachers. If these reports have an impact, perhaps in the not-too-distant future we will see the results in terms of better-prepared students in our freshman mathematics classes.

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